Summary of Pilot Study
Demand Controlled Filtration Project
California Energy Commission

INTRODUCTION

Demand-controlled filtration (DCF) is a method of controlling particle concentration in a clean room by changing the recirculation flow rate based upon real-time measurements of particle concentrations. The demand for filtration may be determined by occupancy or by processes occurring in the room. By lowering average fan speeds (and air change rates), the energy consumed by fan motors is decreased. Fan power is approximately proportional to the cube of the fan speed. Therefore even small changes in the fan speed will cause a large change in the power consumed by the fan.

In order to maintain very low particle concentrations, cleanrooms recirculate air at a high rate (e.g., 600 room air volumes per hour) through highly efficient air filters. Cleanrooms use large amounts of energy for air movement compared to a commercial building that may have an air change rate of 1-2 air changes per hour,. In a previous study (LBNL-38869), we measured a reduction of fan energy consumption of 60 – 80% by using DCF while still maintaining desired cleanliness.

OBJECTIVES

The principal objective of this study was to further investigate the technical feasibility of controlling cleanroom air recirculation through the use of particle counters. Using this strategy, airflow could be optimized while maintaining desired cleanliness levels. Specifically, the following areas were investigated:

1. Identify a type of particle counter that is well suited for DCF and enables fast control response. In our previous study of DCF in an LBNL cleanroom, the particle counter used had 0.3 microns as the lowest bin size and the number of counts in that bin was not adequate for good control of the speed of the recirculation fans.
2. Examine how changes in recirculation fan speed control affected particle concentrations
3. Explore opportunities to perform a demonstration project using DCF with an industrial partner.
4. Estimate energy and cost savings from the use of DCF.

APPROACH

A pilot project was conducted in a 300 ft^2 Class 100 cleanroom at Lawrence Berkeley National Lab to measure particle concentrations using multiple particle counting instruments while changing recirculation fan speeds. The cleanroom is typically used a few hours per week by researchers to make detectors for physics experiments and is unoccupied during other times. This room had previously been used to conduct demand controlled filtration experiments in 1994 and 1995 (LNBL-38869). Significant energy savings (60-80%) were realized by controlling the recirculation fan speed based on real-time particle counts. In this pilot study, the cleanroom was monitored while occupants used the room as well as during unoccupied periods. The speed of the recirculation fans was varied from 100% to 50% and the time between changes in fan speed varied from 1 minute to 1 hour.

Three instruments were used to measure the particle concentrations in the class 100 cleanroom. These were:

1. Lasair Model 1003 by Particle Measuring Systems with particle sizing from 0.1 to 2.0 microns separated into 8 size bins and a sample flow rate of 0.001 cfm.

2. Integrating Nephelometer, Model M903 by Radiance Research

3. Climet Ultimate 1000, 0.10 to 1.0 micron with 6 size bins (0.1-0.15, 0.15-0.2, 0.2-0.3, 0.3-0.5, 0.5-1.0, & >1.0) at a sample flow rate of 1 cfm

Both the Lasair and the Climet are optical particle counters (OPC). They have the ability to quantify particles into bins of different sizes. The Nephelometer does not have the ability to differentiate the size of particles that it detects.

The Nephelometer is a particle counter that produces a single value for each sample of particles that it detects. It operates by measuring light scattering, but does not differentiate by size of particle. This instrument has a lower cost than optical particle counters, such as the Climet and Lasair counters and one of our goals was to reduce the cost of implementing demand controlled filtration.

All three instruments were installed in an adjacent Class 10,000 cleanroom and sample lines pushed through a hole in the wall to an alcove in the Class 100 cleanroom. The three instruments sampled from approximately the same location.

Also, potential industrial partners were contacted to explore performing a demonstration project of DCF in an operating industrial cleanroom. In this demonstration, we plan to implement various control strategies from simple manual control of fan speeds to complex fan speed control using feedback from particle counters.

Finally, estimates of energy and cost savings were updated from those made in our previous report. The cost estimates include buying new hardware as well as implementing various control strategies.

FINDINGS

The instruments began logging data on 27 Jan 04 and stopped on 19 Feb 04. During the first days, the instruments recorded data with the recirculation fan speed at or near 100% as normally operated. The user of the cleanroom continued to use the room and logged when he entered and exited the room. The user occupied the cleanroom on multiple occasions on 27 & 28 Jan 04 as well as 17 Feb 04.

From 5 Feb 04 to 8 Feb 04, the speeds of all four recirculation fans were programmed to change. All fans were programmed to follow the same schedule thus; they were always operating at approximately the same speed. Various schedules were used that varied the fan speed from 100% to 50% in jumps of 10 to 50%. The time between each change in fan speed varied from 1 minute to 1 hour.

The data from the Climet instrument was the most useful and verified that the particle counts (1,000 to 5,000) in the bins <0.3 microns did have greater counts by about a factor of 10 than the 0.3 bin. Also, the counts in the smallest size two bins (0.1 – 0.15 and 0.15 – 0.2) were nearly identical. Therefore, for future tests, an OPC that has a lower bin size of 0.2 microns should be adequate for DCF. With the increased counts in the 0.2-micron size range, the control routine should be well behaved. The data from the nephelometer was nearly useless, as the signal did not vary enough to see any effect of the occupant or the change in fan speed. The counts from the Lasair were very low because of the low sample rate, but occasionally during a high concentration episode, the counts were elevated. Occasionally, the Lasair would record a few 100 counts while the recirculation fans were near 50% of maximum speed.

There was some correlation between changing the fan speed and particle counts but the correlation was not always consistent. After some jumps to a lower fan speed, the particle counts decreased. If the jump to a lower fan speed was too great (to about 50%), then the particle counts increased in general. This points to possibly finding an optimum fan speed to obtain minimum particle counts. This minimum fan speed could be room dependent and also dependent upon the occupancy and processes in the cleanroom.

We were successful in locating two industry partners that committed to participating in a demonstration of this technology. One of the firms located in Fremont, CA was routinely turning down recirculation airflow based upon time of day because the cleanroom was not continuously occupied. The other firm, located in Newport Beach, CA was interested in implementing this technology and had purchased particle counters for this purpose. Demonstrations at both of these sites are planned for the demonstration phase of the project.

CONCLUSIONS

Based on the data collected in the LBNL class 100 cleanroom, an OPC with a sample rate of 1 cfm and a lower size bin of 0.2 microns should be adequate for implementing DCF. Also, not determined in this study, but in our previous work, the sample rate of the particle counter should be 6 seconds or less for quick response to changes in particle concentrations.

Higher fan speeds do not necessarily mean lower particle counts. There may be an optimum recirculation fan speed that is unique to each facility and/or processes occurring in each facility. Further investigation including the planned industrial demonstrations will investigate this further.

Implementing DCF can result in large savings in energy. Since fan energy varies with the cube of fan speed, small changes in fan speed will lead to large changes in fan energy. In our previous study we estimated that implementing DCF had a payback time of 1 to 4 years.

INDUSTRIAL DEMONSTRATIONS

With concurrence of the project advisors, a demonstration phase including this technology is planned under the existing PIER project. These demonstration projects will involve experimenting with various control strategies from the simple to complex. Also, particle counter(s) placement will be explored for optimum energy savings while maintaining the required contamination control.